RESEARCH UNIT 353

DETERMINATION AND DESCRIPTION OF KNOWLEDGE OF THE DISTRIBUTION, ABUNDANCE, AND TIMING OF SALMONIDS IN THE GULF OF ALASKA AND BERING SEA

A SUPPLEMENT TO THE FINAL REPORT

by

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SALMONIDS IN BRISTOL BAY (St. George Basin Region)

INTRODUCTION

In our previous three reports we described the general distribution and average abundance of salmon in the Kodiak, St. George Basin, and Prince William Sound to Yakutat regions of Alaska.[1] Bristol Bay in the St. George Basin contains the most valuable concentration of salmon in Alaska, and consequently there is more detailed information available on the Bristol Bay stocks than on any other stock of salmon in Alaska. Therefore, after completing our general survey of salmon in the three regions, we concentrated our effort on a more detailed description of the abundance of salmon in Bristol Bay.

This report is on salmon in the nearshore waters of Bristol Bay (Fig. 1). The objective was to describe the annual variation in abundance and seasonal timing of the migrations of adult and juvenile (smelt) salmon since 1951.

METHODS

Statistics on Bristol Bay salmon were collected by the National Marine Fisheries Service (NMFS) and Fisheries Research Institute (FRI) during the 19501s and since then by the Alaska Department of Fish and Game (ADF&G). The Informational Leaflets and Technical Data Reports by ADF&G were the major sources of data on sockeye salmon, whereas ADF&G Management Reports were used primarily for statistics on other species of adult salmon.

Statistics on the more abundant sockeye are fairly precise because daily estimates of catches and escapements were available; thus an estimate of the abundance of an annual run of sockeye is probably accurate to within ± 5-lo%. However, only catch statistics were usually available for the other species of salmon and an estimate of the total run had to be made

[1] Stern, L. J., A. C. Hartt, and D. E. Rogers. 1977. Determination and description of knowledge of the distribution, abundance, and timing of salmonids in the Gulf of Alaska and Bering Sea. Pages 586-802 *in* Environmental assessment of the Alaskan Continental Shelf. Vol. 2, Rep. 1-3. Environmental Research Laboratories, Boulder, Colorado.

from these data. The abundance of a run of chum salmon was estimated from the catch and the rate of exploitation on age 0.3 male sockeye salmon (fish of comparable size); i.e., the ratio of run *to* catch of *age* 0.3 male sockeye salmon was multiplied by the catch of chum salmon. This provided a reasonable estimate of the abundance of chum salmon because the two species tended to occur together in the gill-net fishery. Aerial estimates of the number of pink salmon in the escapement to the Nushagak District were available for 5 years (1962, 1964, 1966, 1972, and 1974). In those years the run of pink salmon was estimated from the sum of the catch and estimated escapement and in other years the run was estimated from the catch and the average rate of exploitation for the 5 years when estimates of escapements were available. The annual runs of king salmon, which are must less abundant than the other species, were estimated by doubling the catch, i.e., a rate of exploitation of 0.5 was assumed.

The seasonal timings of the sockeye salmon runs in the fishing districts were taken from a report by P. R. Mundy and O. A. Mathisen.[2] They combined the daily estimates of escapements that are made at the outlets of the Bristol Bay lake systems with the daily catches in the fishing districts to estimate the number of fish that passed through the fishing districts on a given date. Catch statistics alone were available for the other species. These were sufficient to describe the average timing of the runs through the fishing districts but not the annual variation in the timing.

The abundance of juveniles (smelts) that annually migrated out of Bristol Bay was estimated from the abundance of returning adults and estimates of marine survival. The sockeye salmon smelts that migrated from four of the major river systems have been sampled by fyke nets since the early 1950's. In the Wood River and Kvichak systems the sampling provided estimates of the size, age composition, and relative abundance, whereas in the Naknek and Ugashik systems the sampling also provided absolute estimates of the abundance. However, some of the annual estimates of abundance were quite inaccurate; e.g., in some cases more adults returned

[2]Mundy, P. R., and O. A. Mathisen. 1977. Handbook of Bristol Bay sockeye salmon management. Univ. Washington, Fish. Res. Inst. Final Rep. FRI-UW-7720. 100 pp.

than the number of smelts that migrated from tile lake system. Thus, the abundance of returning sockeye according to their freshwater age was divided by an average marine survival for smelts of a given age and average size to estimate the number that had migrated to sea. Sockeye usually spend 1 or 2 years in freshwater prior to their seaward migration and then 2 to 3 years at sea; however, pink and chum salmon migrate to sea in the spring or summer that follows their spawning. They are considerably smaller than sockeye (less than 1 g in weight compared to 4 to 15 g for sockeye) and thus they probably experience a higher mortality in their early marine life. Pink salmon return after 1 year at sea (age 0.1) and chum salmon in Bristol Bay return predominantly after 3 years at sea (age 0.3).

The annual timing of the sockeye smelt migrations was obtained from the daily catches in four of the major river *systems.* It was assumed that 2 days were required for the smelts to reach the center of the commercial fishing district from the outlets of all lakes except Iliamna Lake (Kvichak) and for that lake a 4-day travel time was assumed. No information was available on the timing of chum and pink salmon migrations; however, the abundance of these species is concentrated in the long Nushagak River system and this system is the latest to become ice-free in the spring. Ice breakup in Tikchik lakes , where many of the pink salmon spawn, usually occurs 1 to 2 weeks later than in the Wood River system and a month later than lake systems on the Peninsula. Therefore, it was assumed that pink and chum salmon began migrating into Bristol Bay primarily in July rather than in late May or June, as. is the case with sockeye migrations.

RESULTS

Historical catch statistics on Bristol Bay salmon are summarized in Table 1. These catches provide estimates of the relative abundance and species composition of salmon in Bristol Bay; however, they may not accurately measure the total abundance (run) because fishing effort varied over the years and varied for individual species. The rates of exploitation on sockeye salmon have declined from the early 1900's to the present so the decline in the abundance of the runs has not been as great as the decline in catches (Mathisen 1971). Fishing effort on pink and king salmon is

usually lower than on sockeye and chum salmon which occur together in the fishery, and fishing effort on coho salmon which run in August is less than the effort on all other species.

Sockeye salmon made up about 95% of the catch prior to 1951 and about 86% of the catch since then. The order of abundance of the other species is approximately the same since 1951 as it was in prior years. The average annual catches of chum, pink, and king salmon since 1951 are higher than they were during the period 1901-1950, whereas the catches of sockeye are less in recent years.

Bristol Bay sockeye salmon have also been extensively exploited on the high seas by Japanese fisheries since 1952. The annual rates of exploitation by this fishery on Bristol Bay sockeye have ranged from 3% to 39% (Fredin and Worland 1974). Other species of salmon from Bristol Bay are probably also caught by the high seas fishery; however, no accurate *estimates* of the exploitation are available. Statistics on Bristol Bay salmon that have been collected since 1951 are likely to provide the best estimates of abundance in future years with the possible exception that sockeye salmon may be more abundant in future years.

Annual Abundance of Adult Salmon

Sockeye salmon made up 89% of the salmon runs to Bristol Bay since 1951. Their annual abundance ranged from 2.4 to 53.1 million and in each year they were the most abundant species (Table 2). The relatively high annual variation in the sockeye runs is caused by the cyclical variability in the runs to Iliamna Lake in the Naknek-Kvichak District (Table 3). Even in years that were low points in the cycle, sockeye salmon were always more abundant in the Naknek-Kvichak District than in any of the other districts.

Chum salmon were the next most abundant species; however, they made up only 6% of the salmon runs since 1951. The annual variability in their runs was much less than for sockeye runs and their abundance tended to increase in recent years. About 52% of the chum salmon runs to Bristol Bay since 1951 were *to* the Nushagak District and they were not very abundant in the Egegik and Ugashik districts (Table 4).

Pink salmon are now abundant only in even-numbered years. There were runs in odd-numbered years but these practically disappeared after 1917. The pink salmon runs from 1922 to 1956 probably numbered less than one million annually; however, the runs (primarily to the Nushagak District) increased greatly in 1958 and since then there have been three runs that exceeded two million fish. In some years pink salmon may be a very valuable resource in Bristol Bay but the annual variability in their abundance is high and they are virtually absent in the Egegik, Ugashik, and Togiak districts.

King salmon occur primarily in the Nushagak District and, although they made up only 1% of the total salmon run to Bristol Bay, they are important in that district because of their large size and their presence in early June when other species are absent. Coho salmon occur mainly in the Nushagak and Togiak Districts. They are probably the least abundant of the salmon in Bristol Bay; however, their actual abundance is difficult to determine because their runs occur in August when most canneries have closed and there is relatively little fishing effort.

The Naknek-Kvichak District contains the largest runs of salmon in Bristol Bay because of the periodically large runs of sockeye salmon to Iliamna Lake;and the Nushagak District contains the next most abundant runs of salmon because it contains most of the pink and chum salmon runs. The total run of salmon was greater in the Nushagak District in 3 of the past 26 years (Fig. 2).

Timing of Adult Migrations

The seasonal occurrence of adult salmon in Bristol Bay follows a rather consistent pattern. King salmon arrive in early June and reach a peak abundance in late June. Sockeye and chum salmon arrive in late June but the sockeye reach a peak abundance in early July, whereas the chum salmon reach a peak abundance in mid-July. Pink salmon arrive in mid-July and reach a peak abundance in late July. Adult salmon are nearly absent in Bristol Bay after mid-August. The average daily abundance of salmon entering the Bristol Bay fishing districts is illustrated in

Fig. 3. The abundance of each species is based on the median run during 1951-1976, except the abundance of pink salmon is based on only even-numbered years.

Statistics on the timing of Bristol Bay salmon runs are most accurate for sockeye. In an average year they arrive at Port Moller (outer edge of the bay) from the North Pacific Ocean and Bering Sea on about June 15 and their travel time to the inner fishing districts is about 6 days. Annual variation in the timing of the runs in the fishing districts is illustrated in Fig. 4. Annual variation is partly associated with spring weather conditions. There was warm spring weather and early ice breakup in 1967, 1968, 1970, and 1974; average weather and ice breakup in 1969 and 1973; and colder than average weather in 1966, 1971, and 1975. The earliest that the sockeye arrived was in 1967 when 50% of the run had entered the fishing districts by June 29, and the latest run was in 1971 when 50% of the run had entered by July 10. The means and ranges in dates on which 10, 50, and 90% of the runs passed through the fishing districts in 1956-1975 are as follows:

	Mean	Range
10%	6/27	6/22-7/2
50%	7/4	6/29-7/10
90%	7/11	7/7-7/16

Annual Abundance of Juvenile Salmon

The annual abundances of sockeye smelts were calculated by first arranging the adult runs according to freshwater age and the year in which they migrated to sea (Tables 5 and 6). Estimates of the mean survival from smelts to returning adults (Table 7) were then used to calculate the number of sockeye smelts that migrated from each district in each year. In this method it was assumed that marine survival was a function of the mean size of smelts but relatively constant from year to year. Estimates of the number of pink and chum salmon smelts were made in the same way except that a constant marine survival of 2% was used and all chum salmon were assumed to mature at age 0.3, which is their primary age at maturity in Bristol Bay.

The Naknek-Kvichak District produced 53% and the Nushagak District 32% of the sockeye smelts that migrated during 1950-1974 (Table 8). The annual number that migrated from the Naknek-Kvichak ranged from 13-461 million and averaged 110 million; whereas, for the Nushagak District the numbers ranged from 14-168 million and averaged 66 million. Although more sockeye smelts migrated from the Naknek-Kvichak District over all years, the Nushagak District produced more sockeye smelts in 14 of the 25 years. The annual variation in the number of sockeye smelts migrating from Bristol Bay was relatively greater than the variation in the number of adult sockeye. The coefficient of variation was 129% for smelts, whereas it was 75% for adults.

Annual estimates of the number of pink and chum salmon smelts that migrated from Bristol Bay are given in Table 9. The average annual numbers of pink and chum salmon smelts were 57 and 37 million. Although their average numbers were smaller relative to the average number of sockeye smelts (209 million), they were together more numerous than sockeye in 6 of the past 25 years.

The average total number of smelts (sockeye, pink, and chum) in the annual migrations was 303 million and, of these, 260 million were about equally divided between the Naknek-Kvichak and Nushagak districts. Annual variation in abundance was greater in the Naknek-Kvichak and the abundance of pink and chum salmon was greater in the Nushagak (Fig. 5).

Timing of Juvenile Migrations

The dates on which 10, 50, and 90% of sockeye smelts migrated past the outlets of four of the Bristol Bay lake systems are given in Table 10. Smelts from Ugashik (and presumably Egegik) are the first to enter Bristol Bay. These are followed in order by those from Kvichak, Naknek, and Wood River (Nushagak). The Wood River smelts are still abundant in the outer region of Bristol Bay as late as September (Strady 1974). The daily abundance of smelts that entered Bristol Bay in an average year is illustrated in Fig. 6. The smelts that migrate from a lake system with only one or two lakes (e.g., Ugashik and Kvichak) tend to migrate over a short period, whereas those that migrate from a multi-lake system (e.g., Naknek and Wood River) tend to do so over a long period.

There is considerable annual variation in the abundance of smelts that are in Bristol Bay on a given date. This variation is caused by the annual variation in the number of smelts that are produced by each lake system, the time that smelt migrations begin which is strongly influenced by spring weather conditions, and the differences in timing of the migrations from each lake system. Figure 7 illustrates some of this annual variation that occurred in successive years. In 1963 there was an early migration that contained a very large number of sockeye smelts from Iliamna Lake; whereas in 1964 there was a late migration that contained relatively few smelts from Iliamna Lake.

SUMMARY

The number of juvenile or adult salmon that migrate through Bristol Bay in an average year is best measured by the median number because the annual numbers are not normally distributed. The medians and ranges in the annual numbers of salmon are given in Table 11. The annual estimates of the numbers of smelts and adults are shown in Fig. 8. In most years there is either a large abundance of smelts or a large abundance of adults. Years in which there are very large numbers of sockeye salmon occur at 4- or 5-year intervals. Juvenile pink salmon are usually present only in odd-numbered years and adult pink salmon are usually present only in even-numbered years. The Naknek-Kvichak District produced 36% of the smelts and 54% of the adult salmon in Bristol Bay in an average year; whereas, the Nushagak District produced 50% of the smelts but only 25% of the adults in Bristol Bay in an average year.

Salmon are present in Bristol Bay from May through September; however, they are most abundant in June and July. Figure 9 shows their locations in mid-June of a typical year. From then until the end of July there are usually millions of adults and hundreds of millions of smelts that are passing each other in their migrations to and from Bristol Bay.

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Table 1. Average annual catches of salmon in Bristol Bay by 10-year periods (number of fish in thousands)

Years	Sockeye	Chum	Pink	King	Coho	Total
1893-1900	3,443		15	28	87	3,573
1901-1910	13,043	201	506	112	112	13,974
1911-1920	16,526	538	628	115	128	17,935
1921-1930	14,216	334	98	88	42	14,778
1931-1940	15,971	454	99	37	9	16,570
1941-1950	10,454	338	35	35	24	10,886
1951-1960	6,736	414	165	72	40	7,427
1961-1970	9,314	517	736	105	39	10,711
1971-1976	2,454	666	350	68	29	3,567

Sources: 1893-1970: INPFC Secretariat. MS 1974. Historical catch statistics for salmon of the North Pacific Ocean.
1971-1976: ADF&G Bristol Bay Annual Management Reports.

Table 2. Bristol Bay runs of adult salmon in millions of fish, 1951-1976

Year	Sockeye	Chum	Pink	King	Total
1951	10 .1	0.5		().09	10.7
1952	19.3	0.6	0.1	0.10	20.1
1953	9.4	0.8		0.08	10.3
1954	7.6	1.0	0.2	0.10	8.8
1955	7.7	0.6		0.13	8.4
1956	23.9	0.7	0.2	0.13	24.9
1957	11.0	0.5		0.18	11.6
1958	5.7	0.8	1.8	0.19	8.6
1959	12.9	1.1		0.12	14.0
1960	36.4	2.3	0.6	0.17	39.5
1961	18.1	1.3		0.14	19.6
1962	10.4	1.3	1.5	0.14	13.3
1963	6.9	0.8		0.10	7.7
1964	10.9	1.2	2.5	0.24	14.8
1965	63.1	0.7		0.19	54.0
1966	17.5	0.7	4.1	0.14	22.4
1967	10.4	1.2		0.22	11.8
1968	8.0	0.7	3.2	0.18	12.1
1969	19.0	0.8		0.20	20.0
1970	39.4	1.6	1.0	0.23	42.2
1971	15.8	1.3		0.22	17.3
1972	5.4	1.3	0.2	0.13	7.1
1973	2.4	2.0		0.08	4.5
1974	10.9	1.6	2.0	0.09	14.7
1975	24.1	1.1		0.06	25.3
1976	11.5	2.7	1.7	0.18	16.1
Mean	15.68	1.12	0.73	0.15	17 .68
S.D.	11.71	0.56	1.15	0.05	11.72
Cov. (%)	75	50	158	33	66

Table 3. Number (millions) of sockeye salmon by district and year of the run to Bristol Bay

Year	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak
1951	7.0	1.6	0.5	1.0	0.1
1952	15.5	1.6	0.9	1.1	0.1
1953	4.4	1.8	1.7	1.3	0.l
1954	3.0	2.0	1.5	1.0	0.1
1955	3.3	0.9	0.3	3*0	0.2
1956	18.0	2.3	0.8	2.5	0.4
1957	8.2	1.2	0.6	1.0	0.1
1958	1.8	0.8	0.7	2.4	0.1
1959	5.4	1.7	0.6′	4.8	0.3
1960	26.5	3.3	3*1	3.2	0.3
1961	12.3	3.4	0.7	1.4	0.3
1962	5.7	1.7	0.5	2.4	0.2
1963	2.4	1.7	0.6	1.9	0.3
1964	4.8	2.0	1 . 1	2.8	0.4
1965	44.4	4.6	1.9	1.9	0.3
1966	10.4	2.9	1.2	2.8	0.3
1967	6.5	1.7	0.4	1.5	0.2
1968	5.0	1.0	0.2	1.7	0.1
1969	14.5	1.9	0.3	2.0	0.3
1970	32.6	2.3	0.9	3.2	0.4
1971	9.4	1.9	1.5	2.6	0.4
1972	2.9	1.3	0.1	0.9	0.2
1973	0.8	0.5	<0.1	0.8	0.2
1974	6.5	1.4	0.1	2.8	0.2
1975	18.3	2.1	0.4	2.9	0.4
1976	6.0	1.8	0.5	2.7	0.5

Table 4. Numbers (millions) of chum and pink salmon by district and year of the run to Bristol Bay

Year	Chum salmon					Pink salmon	
	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak	Naknek-Kvichak	Nushagak
1951	.1	*	*	.2	.2		
1952	.1	*	.1	.2	.2	*	*
1953	.3	*	.1	.3	.2		
1954	.2	.1	.1	.4	.2	*	.2
1955	.1	*	.1	.2	.2		
1956	.3	*	*	.3	.1	*	.2
1957	.1	*	*	.3	.1		
1958	.2	*	*	.4	.1	*	1.8
1959	.4	.1	*	.4	.1		
1960	.5	.1	.1	1.0	.6	*	.6
1961	.3	.1	.1	.7	.2		
1962	.5	.1	.1	.4	.3	.1	1.4
1963	.2	*	*	.4	.1		
1964	.3	*	*	.7	.2	.1	2.4
1965	.1	*	*	.4	.2		
1966	.1	.1	.1	.3	.2	.3	3.8
1967	.1	*	*	.9	.1		
1968	.1	*	*	.4	.2	.4	2.8
1969	.1	*	*	.6	.1		
1970	.2	.1	.1	1.0	.2	.1	.9
1971	.2	*	*	.7	.3		
1972	.3	.1	.1	.6	.3	.1	.1
1973	.5	.1	.1	1.0	.4		
1974	.3	*	.1	1.0	.2	1.0	l.0
1975	.3	*	.1	.6	.2		
1976	.7	.1	*	1.6	.3	.5	1.2

* Less than 50,000.

Table 5. Adult returns of sockeye salmon (in millions) arranged by year of smelt migration from the Naknek-Kvichak District

Year of migration	Kvichak and Branch rivers			Naknek River		
	Adult ages		Total	Adult ages		Total
	1.2, 1.3	2.2, 2.3, and 2.1*		1.2, 1.3	2.2, 2.3	
1950	.89	20.56	21.45	.34	1.11	1.45
1951	.23	1,88	2,11	.40	1.93	2.33
1952	.70	.22	.92	,91	.29	1.20
1953	1.24	1.10	2.34	1.94	1.60	3*54
1954	15.47	4.00	19.47	.80	1.54	2.34
1955	.15	.83	.98	,14	.23	.37
1956	.41	.45	.86	.36	.35	.71
1957	1.25	1.11	2.36	1.42	2.55	3.97
1958	29.13	.99	30.12	1.67	.25	1.92
1959	.43	6.01	6.44	.32	.27	.59
1960	,17	3.27	3.44	.28	1.02	1.30
1961	.80	.21	1.01	.63	.62	1.25
1962	1.91	.38	2.29	1.82	1.24	3.06
1963	.70	47.29	47.99	●86	1.73	2.59
1964	.43	2.65	3.18	.27	.85	1.12
1965	.39	4.57	4.96	.45	.65	1.10
1966	2.27	.79	3.06	.54	1.09	1.63
1967	9.61	2.88	12.49	.78	1 S8	1.96
1968	1.80	30.70	32.50	2.54	1.06	3.60
1969	.78	4.20	4.98	.71	.59	1.30
1970	.39	.77	1.16	.27	●55	.82
1971	.46	.19	.65	.31	.29	.60
1922	.19	4.95	5.14	.42	1.93	2.35
1973	.39	14.36	14.7.5	.86	2.15	3.01
1974	.38	2.04	2.75**	.39	3.24	3.67**

* Significant returns of age 2.1 (i.e., greater than 50,000) occurred only from the migrations in 1963, 1967, 1968, and 1974 (years with warm spring weather).

** Includes returns of ages 3.2 and 3.3.

Table 6. Adult returns of sockeye salmon (in millions) arranged by year of smolt migration

Year of migration	Nushagak District									
	Adult ages			Adult ages				Adult ages		
	1.2, 1.3	2.2, 2.3	Total*	1.2, 1.3	2.2, 2.3	3.2, 3.3	Total	1.2, 1.3	2.2, 2.3	Total
1950	1.29	.10	1.42	(.26)	(1.63)	(.05)	(1.94)	(.53)	(.66)	(1.19)
51	.33	.12	.48	(.29)	(1.50)	(.06)	(1.85)	(.66)	(1.02)	(1.68)
52	1.36	.01	1.47	(.20)	(1.26)	(.05)	(1.51)	(.38)	(.77)	(1.15)
53	3.21	.36	3.59	.37	.72	.03	1.12	.12	.19	.31
54	1.43	.41	1.86	.87	1.76	.08	2.71	.73	.24	.97
55	1.18	.12	1.31	.06	.42	.00	.48	.36	.20	.56
56	1.64	.24	1.91	.02	.72	.03	.77	.05	.59	.64
57	4.37	1.48	5.89	.16	2.70	.25	2.11	.05	.43	.48
58	2.02	.65	2.74	4.17	.90	.11	5.18	3.47	.11	3.58
59	.37	.06	.44	.07	.28	.01	1.36	.12	.09	.21
60	2.68	.07	2.81	.10	1.77	.01	1.88	.15	.40	.55
61	1.58	.18	1.79	.21	1.00	.12	1.33	.05	44	.49
62	2.96	.51	3.51	.68	1.34	.02	2.04	.87	40	1.27
63	1.95	.31	2.27	.27	6.16	.03	6.46	.65	1.80	2.45
64	1.56	.07	1.66	.08	1.10	.09	1.27	.18	.33	.51
65	1.76	.16	1.94	.11	1.18	.04	1.33	.03	.19	.22
66	1.16	.14	1.32	.15	.77	.04	.96	.04	.09	.13
67	2.56	.49	3.10	.15	1.53	.08	1.76	.11	.24	.35
68	2.67	.60	3.30	.84	2.49	.07	3.40	1.86	.35	2.21
69	.93	.11	1.05	.23	1.16	.02	1.41	.09	.10	.19
70	1.06	.13	1.29	.07	.96	.02	1.05	.02	.06	.08
71	.65	.03	.68	.11	.28	.00	.39	.01	.01	.02
72	3.31	.71	4.05	.12	2.02	.01	2.15	.01	.07	.08
73	2.00	.53	2.59	.13	.89	.37	1.39	.36	.27	.63
74	1.99	.47	2.51	.10	2.24	.11	2.45	.08	.38	.46

Table 7. Estimates of marine survival of sockeye salmon (1955-73) that were used to estimate number of molts in a migration from number of returning adults

Lake "system	Smelt age	Mean weight (g.)	Mean relative survival (%)	Mean survival (%)
Naknek	I	9.4		15
	II	12.5		24
Kvichak				
Peak years	I	5.0	5	(7)
	11	9.3	10	(14)
Other years	I	5*9	2.5	(4)
	II	11.3	6	(12)
Ugashik	I	6.6		5
	II	12.4		14
Egegik	I	9*4		(9.5)
	II	14.1		(16.5)
	111	16.5		(20.5)
Wood River	I	4.8	6	(3)
(Nushagak)	11	8.3	7	**(7)**

Table. 8. Estimates of the number (millions) of sockeye salmon smelts by district and year of migration from Bristol Bay

Year	Naknek-Kv ichak	Egegik	Ugashik	Nushagak	Togiak	Total
1950	167	13	15	45	4	244
51	32	12	20	14	3	81
52	26	10	13	49	5	103
53	60	8	4	113	7	192
54	262	20	16	54	8	360
55	13	3	9	41	4	70
56	18	5	5	59	6	93
57	60	13	4	168	12	257
58	435	50	70	79	13	647
59	64	9	3	14	3	93
60	38	12	6	92	7	155
61	29	9	4	56	8	106
62	68	15	20	107	15	225
63	461	40	26	70	11	608
64	38	8	6	54	6	112
65	54	9	2	62	4	131
66	71	6	1	41	4	123
67	274	11	4	94	11	394
68	266	24	40	99	19	448
69	60	10	3	33	3	109
70	20	7	1	41	7	76
71	16	3	<1	22	6	47
72	57	14	1	121	9	202
73	120	9	9	76	16	230
74	42	12	3	47	10	114

Table 9. Estimates of the number (millions} of chum and pink salmon smelts by district and year of migration from Bristol Bay

Year	Chum salmon						Pink salmon		
	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak	Total	Naknek-Kvichak	Nushagak	Total
1950	12	2	2	16	5	37	0	0	0
51	11	4	2	22	5	44	1	2	3
52	2	1	3	12	5	23	0	0	0
53	12	1	0	15	4	32	0	11	11
54	4	1	1	13	4	23	0	0	0
55	12	1	1	19	3	36	0	10	10
56	22	3	1	22	6	54	0	0	0
57	27	4	4	52	28	115	2	90	92
58	12	4	3	33	14	66	0	0	0
59	26	3	2	20	13	64	1	31	32
60	12	1	1	18	6	38	0	0	0
61	13	2	2	34	8	59	3	71	74
62	4	1	1	22	8	36	0	0	0
63	6	2	4	13	8	33	5	120	125
64	6	1	2	44	6	59	0	0	0
65	6	1	1	18	10	36	14	189	203
66	5	1	0	29	5	40	0	0	0
67	10	3	2	52	12	79	22	137	159
68	12	2	1	35	13	63	0	0	0
69	13	4	4	28	16	65	3	44	47
70	26	3	3	48	21	101	0	0	0
71	17	2	3	49	8	79	6	6	12
72	15	1	3	29	9	57	0	0	0
73	34	3	2	82	13	134	51	51	102
74							0	0	0
75							26	60	86

Table 10. Timing of smelt migrations from Bristol Bay river systems. Dates on which 10, 50, and 90 percent of smelts migrated past the lake outlet

	Kvichak			Ugashik			Naknek			Wood River		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
1951										6/7	6/23	*7/11*
1952										6/12	6/25	*7/18*
1953										6/3	6/17	*6/23*
1954										6/2	6/10	*6/15*
1955	6/5	6/5	6/8							6/26	7/10	*7/15*
1956	6/1	6/5	6/15							6/16	7/6	*7/12*
1957	5/31	6/1	6/24							6/11	6/24	*6/26*
1958	5/22	5/27	6/13	*5/23*	5/29	*6/5*	5/28	6/21	7/7	6/9	6/15	*7/1*
1959	5/26	5/30	6/1	*5/29*	5/31	*6/15*	6/3	6/17	7/10	6/6	6/18	*6/25*
1960				*6/2*	6/5	*6/12*	6/4	6/13	6/25	6/2	6/18	*7/10*
1961				*5/16*	5/28	*6/20*	6/6	6/14	7/1	6/5	6/15	*7/2*
1962	6/2	6/9	6/15	*5/16*	5/30	*6/9*	6/2	6/8	6/18	6/13	6/21	7/5
1963	5/25	5/27	6/7	*5/16*	5/31	*6/10*	6/1	6/19	7/1	6/9	6/16	*7/2*
1964	6/4	6/7	6/13	*5/25*	6/5	*6/9*	6/9	6/16	7/2	6/21	6/30	*7/5*
1965	5/24	5/26	5/29	*5/27*	6/3	*6/13*	6/3	6/15	6/27	6/18	7/1	*7/11*
1966	6/5	6/7	6/11				6/6	6/14	6/22	6/17	6/26	*7/8*
1967	5/26	6/1	6/9	*5/23*	5/28	*6/8*	5/31	6/8	6/26			
1968	5/21	5/23	5/27	*5/23*	5/27	*6/5*	6/3	6/8	6/26			
1969	5/28	6/1	6/12	*5/25*	5/30	*6/5*	6/4	6/9	6/29			
1970	5/22	5/27	6/3	*5/19*	5/29	*6/6*	6/5	6/6	6/26			
1971	6/10	6/10	6/15				6/9	6/13	6/25			
1972	6/8	6/12	6/17	*5/28*	6/12	*6/18*	6/9	6/11	6/20			
1973	5/23	5/25	5/31	*5/27*	5/29	*6/4*	5/28	6/3	6/13			
1974	5/23	5/27	6/1	*5/27*	5/29	*6/7*	5/31	6/3	6/21			
1975		-	-				6/6	6/9	6/27	6/14	7/2	7/13
1976	6/9	6/11	6/13							6/20	7/14	7/29
Means	5/30	6/2	6/9	5/24	5/31	6/10	6/4	6/12	6/26	6/12	6/24	7/6

Table 11. Medians and ranges in the number of salmon smelts (1950-1974) and adults (1951-1976) in Bristol Bay (number of fish in millions)

	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak	Bay Total
Smelt						
Sockeye						
Median	68	10	5	62	7	123
Low	16	3	<1	14	3	47
High	461	50	70	168	19	647
Chum						
Median	12	2	2	26	8	55
Low	2	1	0	12	3	23
High	34	4	4	82	28	134
Pink (odd year)						
Median	3	0	0	51	0	74
Low	0			2		3
High	51			189		203
Adult						
Sockeye						
Median	6.5	1.7	.6	2.2	.25	10.9
Low	.8	.5	<.1	.8	.1	2.4
High	44*4	4.6	3.1	4.8	.5	53.1
Chum						
Median	.2	<.1	<.1	.4	.2	1.0
Low	.1	0	0	.2	.1	.5
High	.7	.1	.1	1.6	.6	2.7
Pink (even year)						
Median	.1	0	0	1.0	0	1.5
Low	<.1			<.1		.1
High	1.0			3.2		4.1

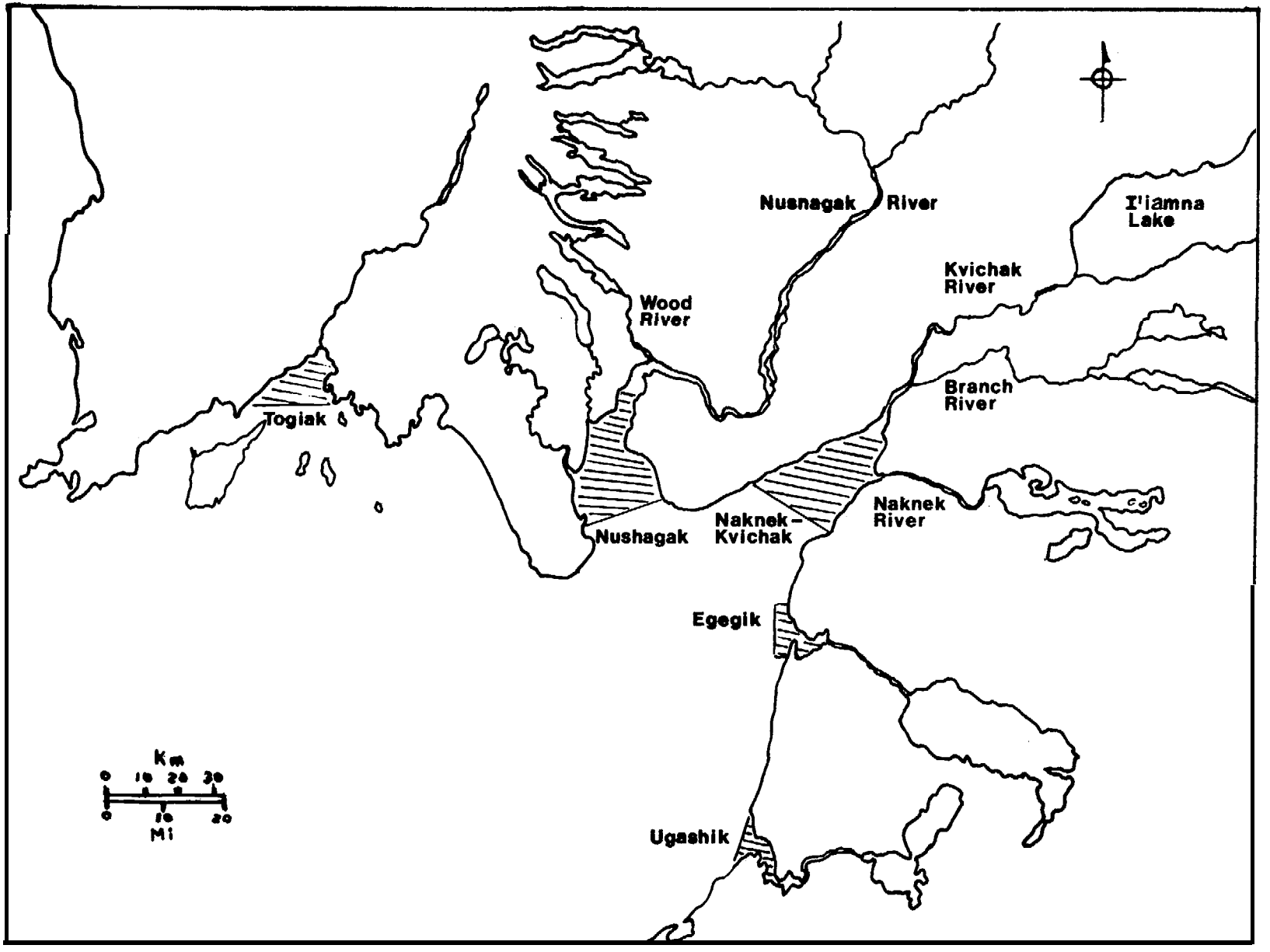

Fig. 1. The major river systems and fishing districts in Bristol Bay.

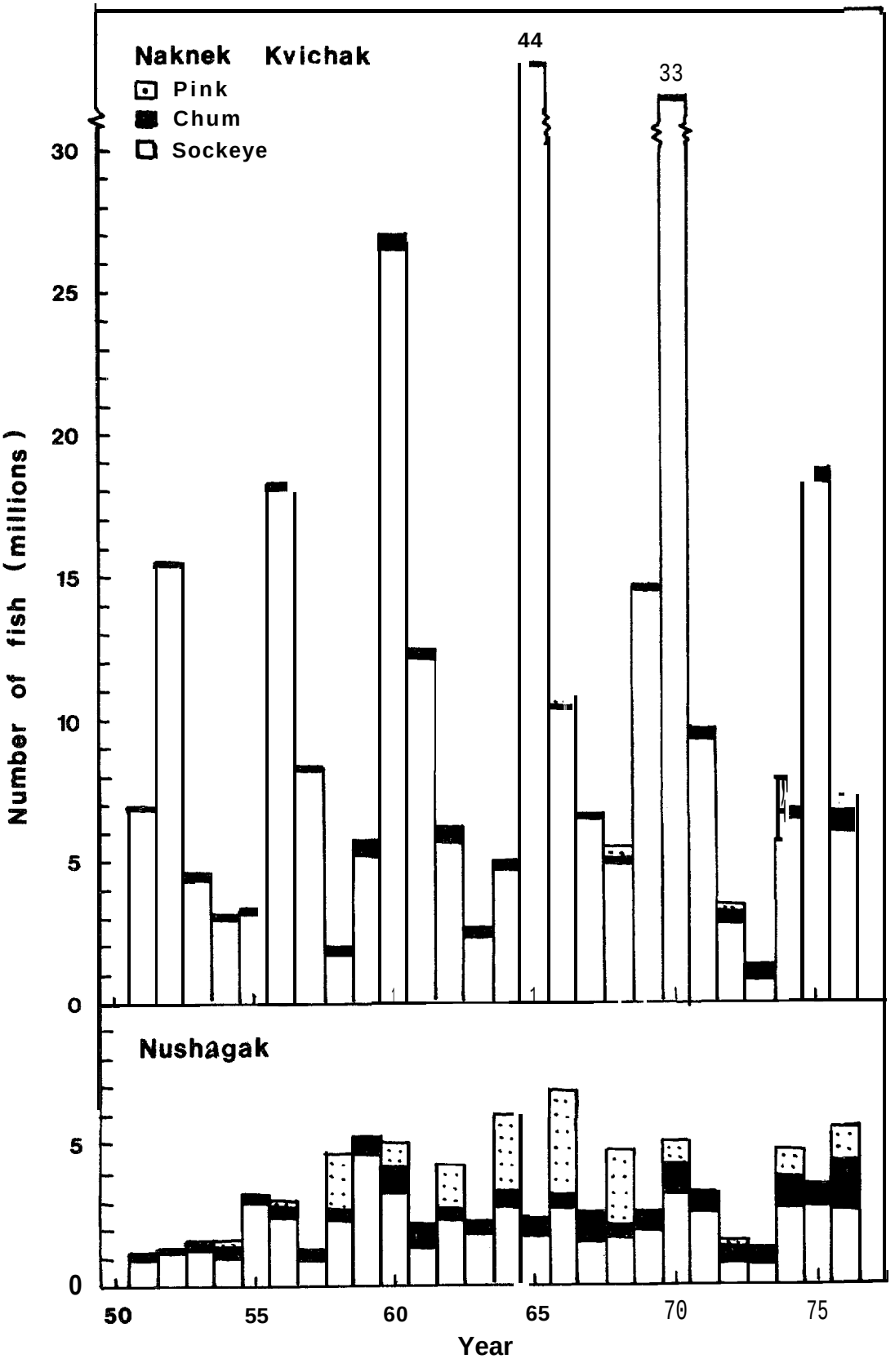

Fig. 2. Runs of salmon to the Naknek-Kvichak and Nushagak Districts of Bristol Bay, 1951-1976.

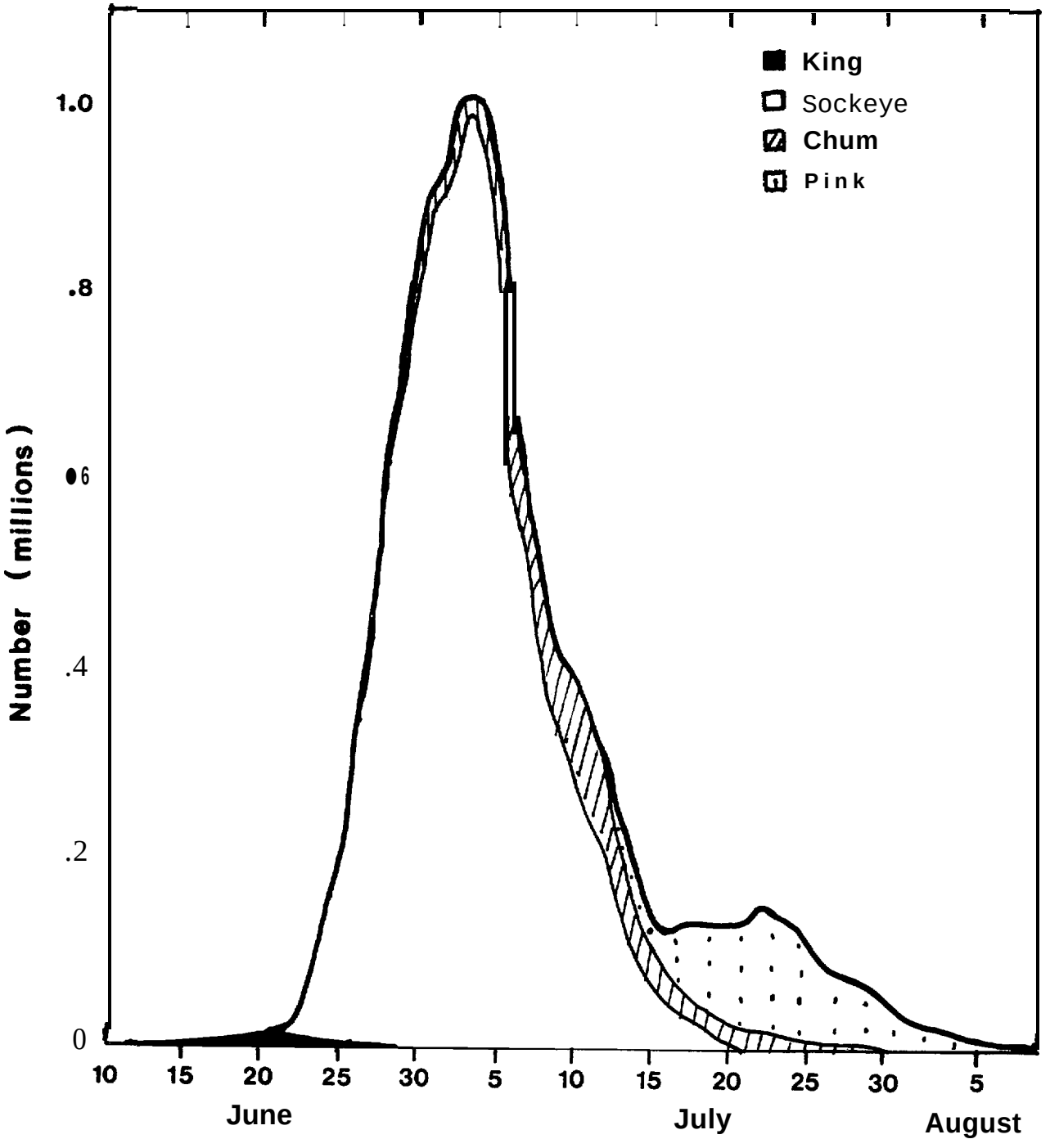

Fig. 3. Daily abundance of adult salmon entering the fishing districts of Bristol Bay in an average even-numbered year. Pink salmon would be nearly absent in an odd-numbered year.

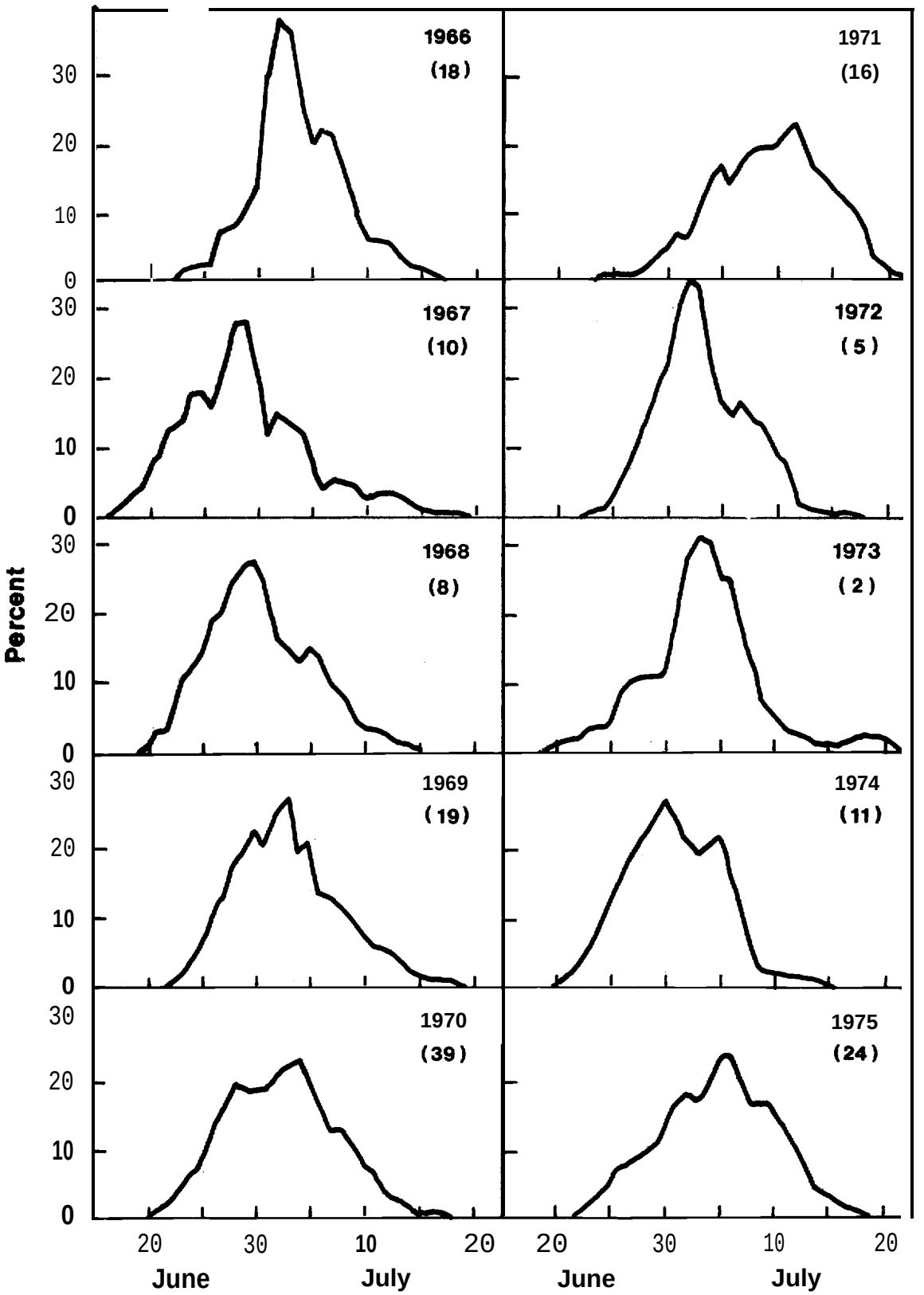

Fig. 4. Timing of the sockeye salmon runs in Bristol Bay, **1966-1975.** Percent in the fishing districts on a given date plus the percent on the previous and following dates. Run in millions is given in parentheses.

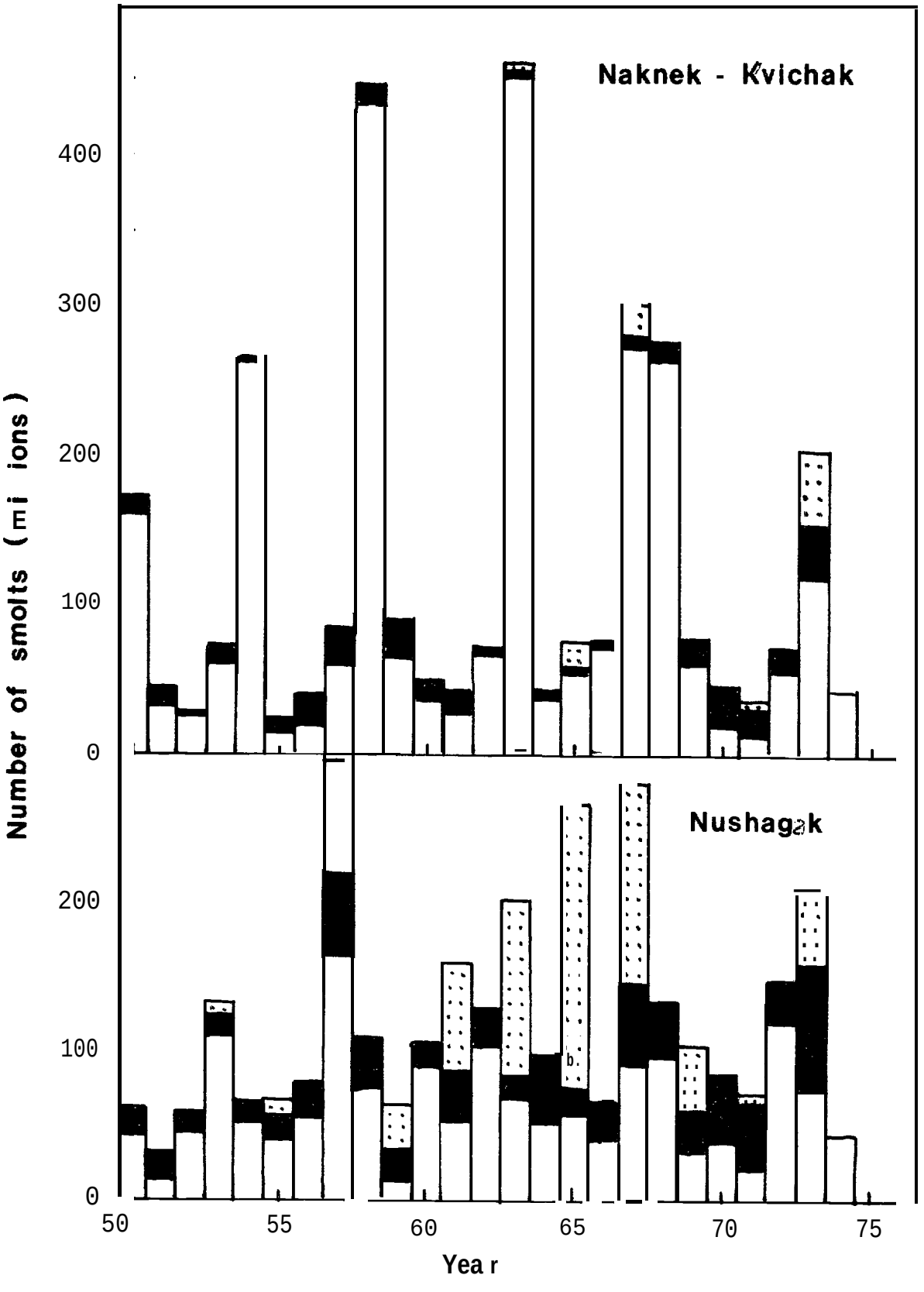

Fig. 5. Annual abundance of smelts that migrated from the Naknek-Kvichak and Nushagak Districts.

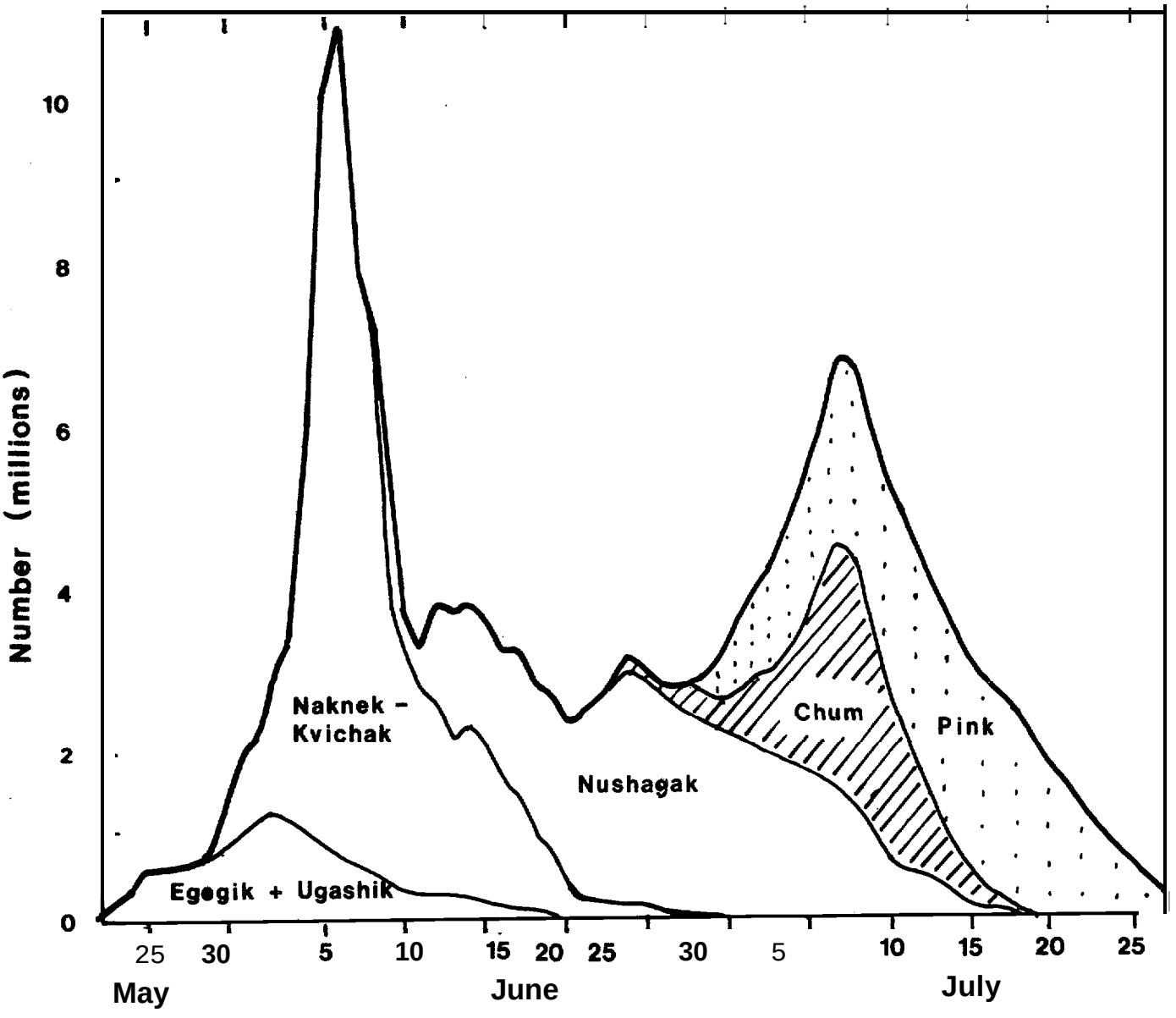

Fig. 6. Daily abundance of salmon smelt entering Bristol Bay in an average odd-numbered year, sockeye salmon for each district and pink and chum salmon from the Nushagak District only. Pink salmon would be nearly absent in an even-numbered year.

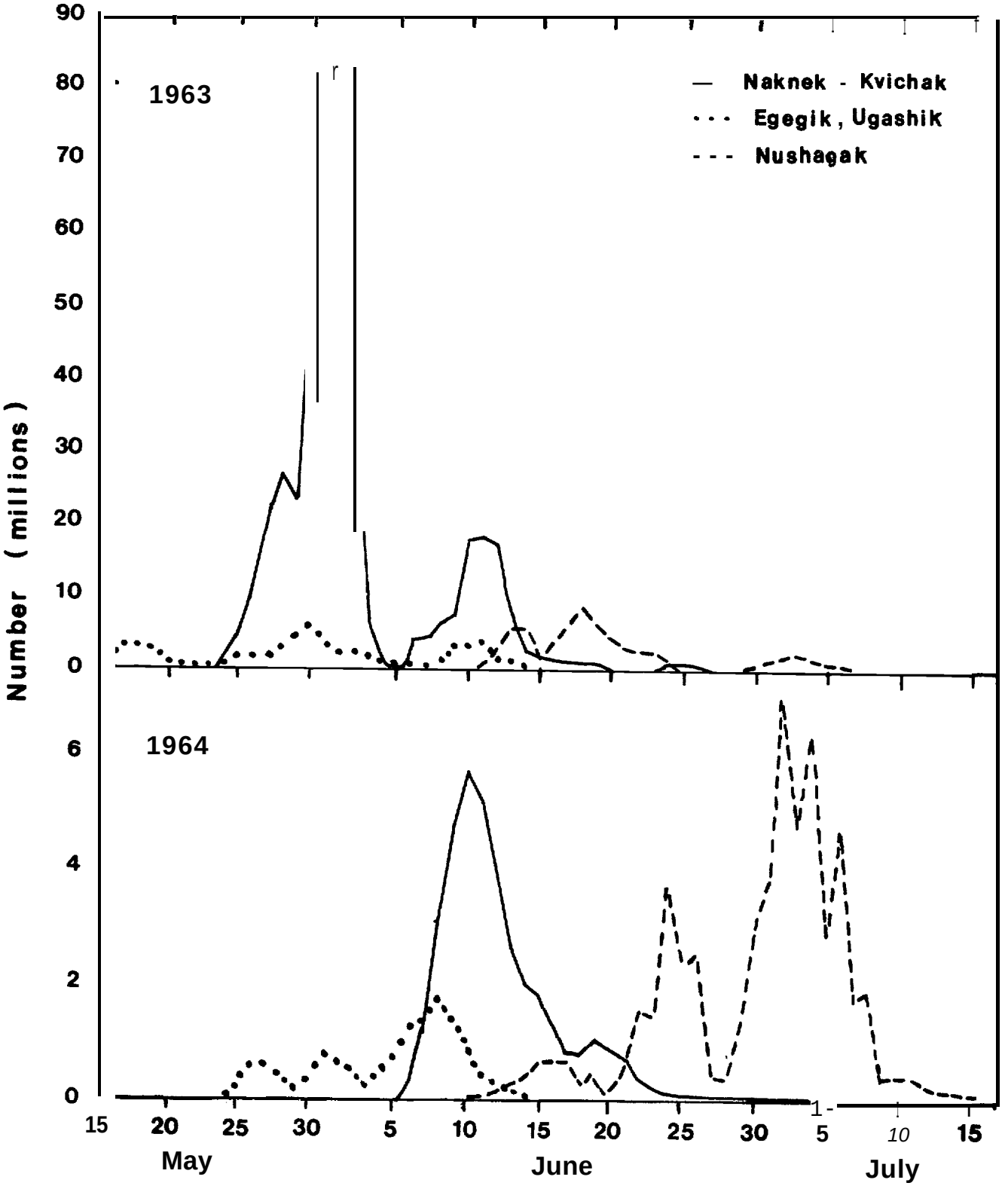

Fig. 7. Daily numbers of sockeye salmon smelts that entered Bristol Bay in 1963 and 1964.

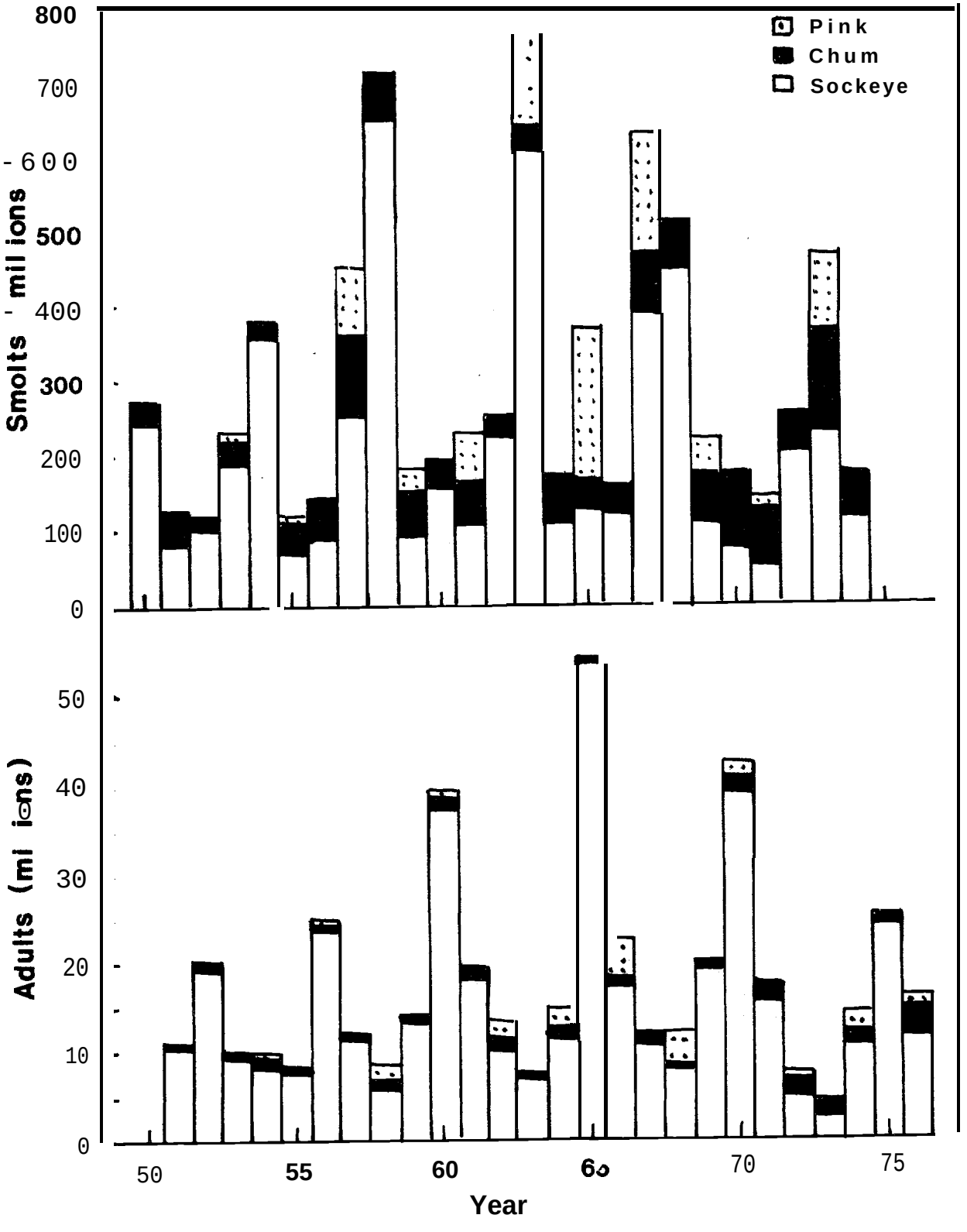

Fig. 8. Annual abundances of smelt and adult salmon in Bristol Bay.

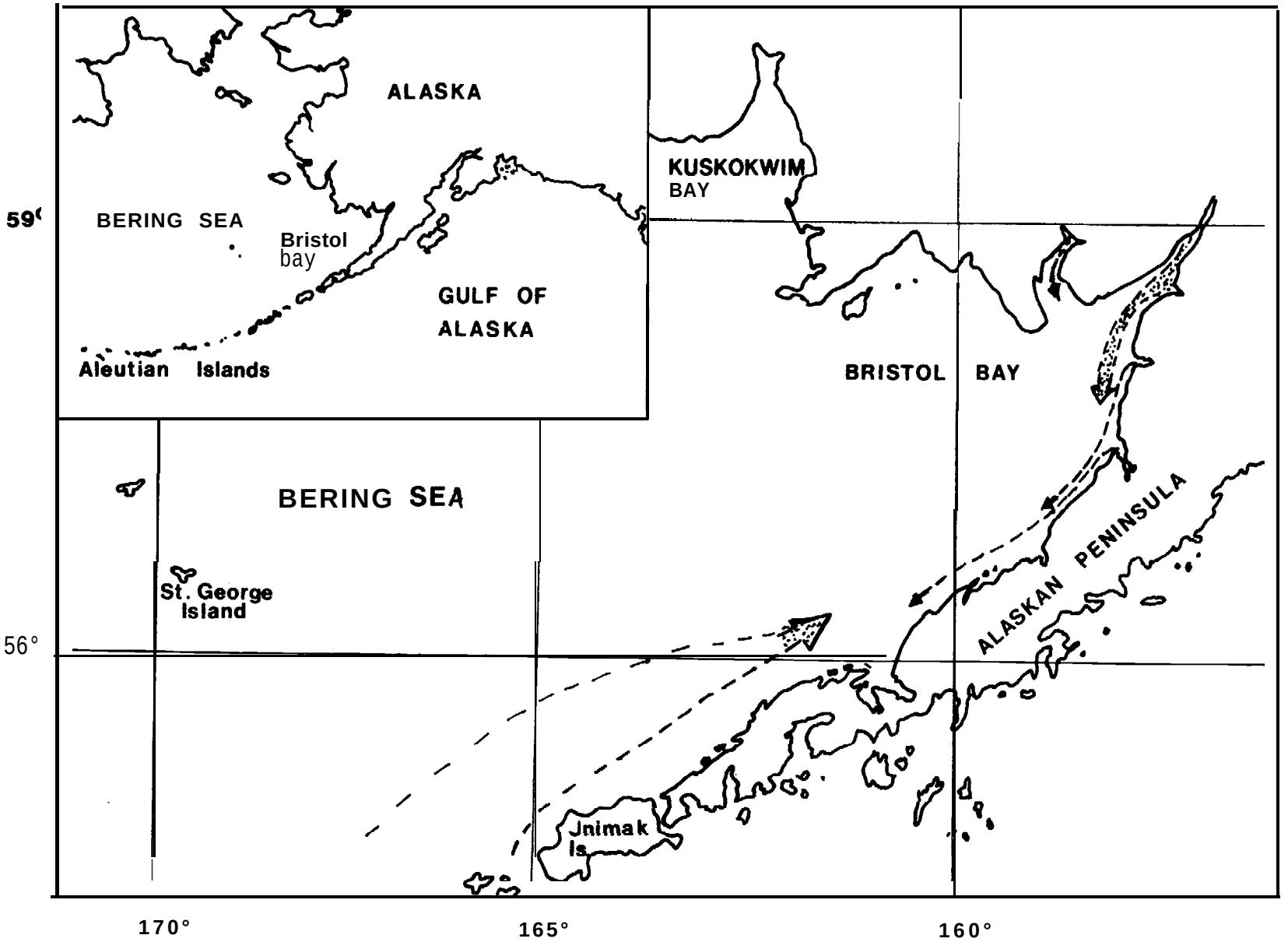

Fig. 9. Locations in mid-June of adult salmon entering and juvenile salmon leaving Bristol Bay.